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A QUANTITATIVE STUDY OF VARIATION IN THE SMALLER NORTH-AMERICAN SHRIKES.

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CONTENTS.

I. INTRODUCTION.

THE work described in this paper was begun in the fall of 1898, and was carried on at Harvard University during the year 1898–99 under the direction of Dr. Charles B. Davenport. It was completed during the winter of 1899–1900.

It was my desire to employ statistical methods in the study of variation in a group of birds, and to apply the "Precise

Criterion of Species" of Davenport ('98) to a problem in bird classification. The smaller American shrikes of the genus Lanius appeared to me to offer favorable material for the application of quantitative methods to the solution of an interesting taxonomic problem.

The shrikes are a group of passerine birds more or less generally distributed in northern Europe and North America, and probably of circumboreal origin. The large northern shrike, *Lanius borealis* Vieill., of North America grades into the great gray shrike, *L. excubitor* Linn., of Europe; and it exhibits a strong tendency towards individual variation.

In the United States, Mexico, and southern Canada the breeding[1] shrikes are not essentially different from the northern shrike, *L. borealis*, in certain of its color phases, except for smaller size and the more or less complete disappearance of a conspicuous barring or mottling of the breast in adults. This barring of the breast is persistent in most adults of *L. borealis* and characteristic of the juvenile plumage of the southern shrikes, a fact of much phylogenetic interest.

According to the nomenclature of the American Ornithologists' Union there are at present recognized three races or subspecies of the southern or smaller shrikes, which are as follows: *Lanius ludovicianus ludovicianus* Linn., *L. ludovicianus excubitorides* Swains., and *L. ludovicianus gambelli* Ridgw. Subspecies *gambelli* includes the shrikes of California and vicinity. The shrikes of the rest of the country are classed as either ludovicianus or excubitorides, the former being typical in the south central states and the latter in the vicinity of Colorado.

The shrikes of New England and the north central states have been variously classed, by different systematists, as either ludovicianus or excubitorides. Palmer ('98) has proposed for the shrikes of this intermediate region a new subspecies, migrans, whose validity, I believe, can be well tested by the "Precise Criterion" method.

[1] In this paper the breeding range only is considered in discussing geographical distribution.

We have in the shrikes the following eight important variable characters:

1. Length of tail.
2. Length of wing.
3. Length of bill.
4. Depth of bill.
5. Curvature of culmen.
6. Color of dorsal surface of head and back.
7. Color of upper tail coverts.
8. Color of breast.

II. Material.

While the shrikes make good subjects for a study of variation, there has been an unfortunate difficulty in obtaining material in amounts as large as is desirable. Shrikes are not especially common birds in the regions most collected in, and they are considered rare in most parts of New England. They are certainly not abundantly represented in collections of birds, and many of the skins that were obtained were imperfect, or did not come from the breeding areas of the birds.

I have been able to procure measurements of two hundred and ninety-four available skins, obtained from the following sources:

Mr. William Brewster, Cambridge, Mass.	174 skins.
National Museum, Washington, D. C.	64 "
Museum of Comparative Zoölogy	18 "
Mr. J. H. Gaut, Washington, D. C.	15 "
Mr. C. F. Batchelder, Cambridge, Mass.	8 "
Dr. A. K. Fisher, Washington, D. C.	5 "
Mr. N. Hollister, Delavan, Wis.	4 "
Oberlin College Museum, Oberlin, Ohio	4 "
Carnegie Museum, Pittsburg, Pa.	1 "
Mr. William Palmer, Washington, D. C.	1 "

The numbers given do not include skins which, for various reasons, could not be used. I wish here to express my thanks to the gentlemen who have secured for me the loan of the above-mentioned material, and especially to Mr. William Brewster for many courtesies received.

GEOGRAPHICAL DISTRIBUTION.

	MALE.	FEMALE.		MALE.	FEMALE.
Arizona	16	13	Montana	4	3
British Columbia	1	0	Nevada	2	0
California	15	21	New Mexico	0	1
Colorado	1	2	New York	5	2
Connecticut	1	0	North Carolina	3	0
District of Columbia	6	2	North Dakota	1	0
Florida	45	23	Ohio	3	1
Georgia	8	6	Ontario	0	1
Illinois	10	3	Pennsylvania	1	1
Indiana	1	0	South Carolina	16	2
Indian Territory	0	1	Tennessee	1	1
Kentucky	1	0	Texas	7	5
Maine	0	1	Utah	0	1
Massachusetts	1	2	Virginia	4	10
Mexico	17	16	Wisconsin	0	1
Minnesota	1	0	Wyoming	3	1
			Total	174	120

III. METHODS.

A. General Precautions.

It is hardly necessary to say that work of this kind should be done with material in normal condition. I have made no measurements where mutilations existed, and only adult birds bearing good evidence of representing their breeding ranges have been used. It has been necessary to reject a number of skins because of lack of data as to sex. As male and female shrikes are essentially alike in color and differ little in size, it is not possible to verify the original determinations of sex; however, there has been no noticeable confusion in this respect.

No attention has been given to the subspecific distinctions appearing on the labels of skins, for I have considered it important to avoid all possibility of bias of opinion which attention to previous classification might give.

B. Measurements of Variable Characters.

1. *Linear Measurements. Length of Wing.* — The shortest distance between the wrist and the tip of the wing was measured with a pair of dividers, the wing being folded naturally at the side of the body. The left wing was taken in every case for the measurement.

Length of Tail. — This measurement was made from the papilla of the uropygial gland to the extreme end of the tail feathers. One arm of the dividers was placed with its point resting on the anterior face of the papilla. On account of mutilation and frequent difficulty in finding the papilla, the measurement has often to be omitted. Great precision cannot be obtained, as there is irregularity in the relative position of the papilla in the drying of the skin, and there is also usually some wearing away of the distal ends of the rectrices. When the latter were much frayed no measurement was attempted.

Length of Bill. — The only satisfactory method found for measuring the length of the bill was to take the shortest distance between the nostril and the distal apex of the upper mandible. The point of one arm of the dividers was placed against the most distal face of the nostril. I have had to make allowance in some cases for the wearing away of the distal apex of the upper mandible, though the amount of wear is too small to materially affect the measurement.

Depth of Bill. — The greatest dorso-ventral diameter of the bill near its base was determined. There is considerable liability to error here on account of lack of uniformity in the articulation of the mandibles in the dried skin, and I found it necessary to reject quite a number of skins on this account.

2. *Curvature of Bill.* — This is a character of the distal half of the culmen. Its quantitative expression is a matter of some difficulty, for we have here a curve which is not the arc of a circle nor a parabola, nor does it correspond to any geometrical figure. Then, too, the form and size of the bill are such as to render it impracticable to make precise measurements directly. To meet the latter difficulty it was decided to try to trace on paper the enlarged projection of the outline of the bill. After

some experimentation, the following apparatus was devised. Fig. 1 is a diagram of an enlarging camera with a box in front of the lens, at the left in the figure. A circular aperture for the passage of light was made in one side of the box, the oppo-

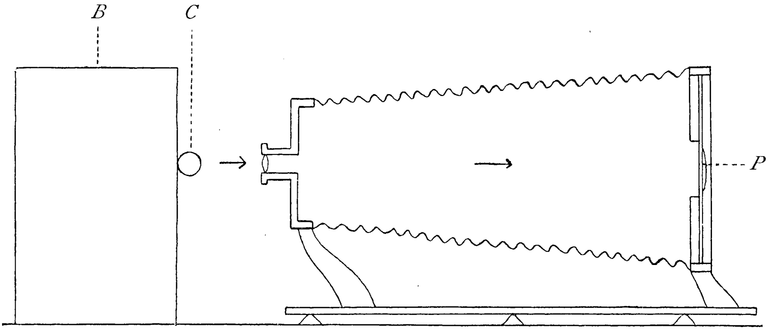

FIG. 1. — Longitudinal section of enlarging camera apparatus. *B*, box; *C*, paper cylinder; *P*, photographic paper in holder.

site side being removed. At one side of the aperture (*A*, Fig. 2) a simple cylinder (*C*, Figs. 1 and 2) of stiff paper just large enough to admit a shrike skin was fastened to the outside of the box in a nearly horizontal position by a single tack.

Orientation was then secured for any skin by the following simple adjustments: (1) rotation of the skin in the cylinder around its longitudinal axis; (2) rotation of the cylinder on the axis formed by the tack; (3) moving the skin in the cylinder towards or away from the aperture; (4) rotation of the box on a vertical axis.

The apparatus was arranged so that the bill of a shrike was about seven inches from the front of the lens and its median plane at right angles to the axis of the camera. Strong diffused daylight was then allowed to pass through the aperture of the box past the bill, and into the lens of the camera, as shown by the arrows in Fig. 1. In the plate-holder at the back of the camera was placed a piece of "velox" paper (a rapid printing photographic paper) about 2×3 inches

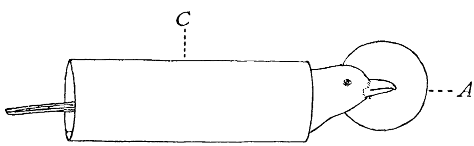

FIG. 2. — Paper cylinder (*C*) holding bird so that the bill projects before aperture (*A*).

in size. An exposure of seventy-five seconds was ordinarily sufficient to obtain a picture, which appeared on development as a white area on a black ground. A magnification of 3⅓ diameters was secured, care always being taken to have the distance of the bill from the lens constant. An outline of the culmen of practicable working size having been thus obtained, the next step was the analysis of the curve.

It was highly desirable to have one simple criterion of the curvature, if one sufficiently representative could be found. In Fig. 3, which represents the outline in a representative case, a great increase in the sharpness of the curvature is seen

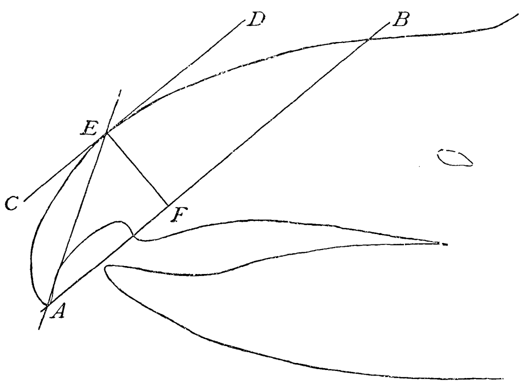

FIG. 3. — Diagram of bill showing method of measuring curvature of culmen. *AB* equals distance of *A* from nearest margin of nostril; *CD*, tangent to outline of culmen parallel to *AB*; *EF*, perpendicular at point of tangency, *E*; *EAF*, angle embraced between the two chords of the culmen, *AB* and *AE*.

towards the distal end of the culmen; the sharpness of curvature varies in different individuals. The point where the rapid increase begins was found on inspection to be sufficiently uniform in position to suggest the idea of comparing in different individuals the angle embraced between two chords of the curve of the culmen, each of them terminating at the distal end of the culmen. The proximal ends of the two chords were selected by the following method: one was established at a point on the culmen as far from its apex as the apex was from the nearest margin of the nostril. The distance of the nostril from the tip of the culmen, of course, could not be measured on the photographic silhouette print; it was therefore determined

by measuring the actual distance in the specimen and multiplying that value by the linear magnification of the print. The nostril distance was used because the nostril was found to be the only point sufficiently definite and constant for the proximal limit. This chord (*AB*, Fig. 3) served as a base line. A line (*CD*) parallel to the base line and tangent to the culmen was next drawn, and at the point of tangency (*E*) a perpendicular (*EF*) was erected between the lines. It was then a simple matter to measure the lines *AF* and *EF*, and with a table of natural tangents to determine the angle *EAF*. This is the angle that has been adopted as a criterion of curvature in the shrike bill. It is easily seen that there might be an infinite number of small variations in the outline of the culmen, especially in the part distal to the point *E*, which would not affect the angle *EAF*; but I believe that a correlation is to be expected between the curvatures in various portions of the culmen, so that it is probable that any considerable variation in outline elsewhere would affect the curvature in the region of *E* and thus find expression in the angle *EAF*. In order, however, to have something more than a subjective impression on this matter, I made a second series of measurements with half the length of the line *AB* used as a chord. The result of these measurements, and their deviations from those of the first set, are given on page 294.

3. *Color Measurements.* — For the quantitative determination of color, the "color mixer" was suggested. A simple form of color mixer — the Bradley Milton Color-Top — was employed. This instrument has a graduated disk, with superimposed paper disks of five different colors, which can be so adjusted as to make compound disks exposing two or more colors. On being rotated at high speed these colors are mixed into one, which is a combination of the colors used in the proportions of the number of degrees of each exposed. With the aid of this apparatus it is therefore possible to determine the proportions of these primary colors entering into any color effect which may be produced by various combinations of them. To determine the composition of any color in nature, it is necessary to reproduce empirically that color in the top and note the

combinations that have given the desired effect. In practice, however, the following conditions were found essential to accurate estimation of color: (1) Uniform strong diffused daylight, preferably coming from a skylight or north window and not subject to strong reflections from colored surfaces; (2) frequent comparison with previously made estimates; (3) careful comparison of the color obtained by the top with that of the plumage, whose color is being measured, both being viewed from different directions.

I found it impracticable to make color estimates for more than two hours continuously, because of color fatigue of the eye.

In spite of the above precautions, there are limitations to the use of the color-top. In the estimation of color, the personal equation plays an important part. Then, too, the surface of the color disks is very different in character from that of feathers. The peculiar luster or sheen so characteristic of a bird's plumage cannot be imitated by the color mixer. In estimating the color of the breast, more or less mottling, which exists in some cases, increased the difficulty. In such cases I have attempted to estimate the mean color. Some apparatus for blending a complex pattern into one color would be very desirable. I do not attempt to maintain that estimates of the same material by another person would exactly agree with mine; but I believe that I have a consistent classification of individuals according to color.

After several weeks of experimentation I found that, though there were traces of blue, red, and yellow, the colors black and white were by far the most important elements in the areas measured. Therefore I have taken as the color criterion the amount of black, or the melanism, of the color area described; and color estimates appear in the tables as percentages of melanism. I have found it more difficult to estimate colors containing more than 50% of white than those in which black predominated, and I have not attempted to make fine distinctions as to melanism in the lighter color areas. The large amount of black necessary to produce even the lightest grays in the color mixer was a matter of surprise to me. To

properly appreciate the estimates of color given in this paper, a color mixer should be used to reproduce the combinations given.

Ability in the discrimination of color I have found to be much developed by experience. The color determinations of my first three months' work were rejected, as increased power of discrimination made more accurate results possible.

C. Geographical Areas.

The material described in this paper has been collected from a territory of great size and varying conditions, and it is therefore desirable to compare individuals both as parts of a single group and in subdivisions corresponding to natural life areas, so that correlations between individual variability and geographical variation may be made. I have adopted the life areas employed by Allen ('93) for the territory covered by my material, which are four in number:

1. *Austroriparian Subprovince*, embracing North and South Carolina, Georgia, and Florida.
2. *Appalachian Subprovince*, embracing Maine, Massachusetts, Connecticut, District of Columbia, Virginia, Ontario, New York, Pennsylvania, Indiana, Kentucky, Ohio, Illinois, Wisconsin, Minnesota, and North Dakota.
3. *Campestrian Subprovince*, embracing British Columbia, Montana, Wyoming, Colorado, Indian Territory, New Mexico, Texas, Idaho, Utah, Arizona, and Nevada.
4. *Sonoran Subprovince*, embracing California, Lower California, and Mexico.

A comparison of variations for still smaller areas is desirable, but this, to be useful, would require more material than I have been able to obtain. The subspecies of shrikes have the distribution given by Palmer ('98), excepting gambelli (Palmer did not consider the western shrikes), which agrees very well with the above life areas. The inhabitants of each are:

SUBPROVINCE.	SUBSPECIES.
Austroriparian	= ludovicianus
Appalachian	= migrans
Campestrian	= excubitorides
[Sonoran	= gambelli]?

IV. Results.

A. Indices of Variability.

1. *Wing and Tail.* — In Figs. 4–8, frequency polygons based on measurements of various dimensions, the position of the mean class is indicated by a heavy vertical line. In Fig. 4 are given frequency polygons for the lengths of the wing (4 *A*) and tail (4 *B*) of all available male shrikes. They show a striking absence of variability for these characters in a series of individuals representing four subprovinces with greatly varying conditions.

In Tables I–III are given correlations between the length of wing and the length of tail. I have used the method of Duncker (Davenport, '99, p. 33) in determining coefficients of correlation. The "probable error" has also been determined by the following formula (Davenport, '99, p. 34), in which ρ is the coefficient of correlation.

$$\text{P. E. } \rho = \frac{0.6745\,(1 - \rho^2)}{\sqrt{n}\,(1 + \rho)}$$

On comparing Tables II and III, we find that Florida shrikes have a greater length of tail in relation to the length of wing than shrikes from the Appalachian subprovince.

The correlation in these characters for the series from the Appalachian subprovince is seen to be 0.157− greater than that of the Florida series. This difference is possibly due in part to the skewness of the curves of frequency for these series, which renders precise correlations difficult.

Table I. — 140 Male Shrikes from the Entire Region.

Mean of wing = 99.06 + mm. Mean of tail = 101.571 + mm.
σ_1 = 2.74 + mm. σ_2 = 3.48 + mm.

		Wing, Subject.				Tail, Relative.					
X_2		−7	−5	−3	−1	0	2	4	6	8	
Rel. class		94	96	98	100	102	104	106	108	110	mm.
Sub. class (I)	X_1										(II)
94 mm.	−5			4	3	1					
96 mm.	−3	2	2	6	8	3		1			
98 mm.	−1	1	3	9	11	11	6	4			
100 mm.	0		1	5	9	6	7	6	2		
102 mm.	2			2	1	6	3	2			
104 mm.	4					1		5	3	3	
106 mm. (III)	6						2		1		(IV.)

$\rho = 0.5688 +$ P. E. $\rho = \pm\ 0.038 +$

TABLE II. — 41 MALE SHRIKES FROM FLORIDA.

Mean of wing = 97.463 + mm. Mean of tail = 102.292 + mm.
σ_1 = 2.29 + mm. σ_2 = 3.14 + mm.

		WING, SUBJECT.				TAIL, RELATIVE.				
X_2		−6	−4	−2	0	1	3	5	7	
Rel. class		96	98	100	102	104	106	108	110	mm.
Sub. class (I) X_1										(II)
94 mm.	−3		4	3	1					
96 mm.	−1	1		5	1					
98 mm.	0		1	1	7	4	3			
100 mm.	2				2	2	3	2		
102 mm.	4									
104 mm. (III)	6								1	(IV)

$\rho = 0.639 +$ P. E. $\rho = \pm 0.0487$

TABLE III. — 28 MALE SHRIKES FROM THE APPALACHIAN SUBPROVINCE.

Mean of wing = 99.357 + mm. Mean of tail = 99.43 + mm.
σ_1 = 2.31 + mm. σ_2 = 3.063 + mm.

		WING, SUBJECT.			TAIL, RELATIVE.				
X_2		−5	−3	−1	0	2	4	6	
Rel. class		94	96	98	100	102	104	106	mm.
Sub. class (I) X_1									(II)
96 mm.	−3	2		1	1				
98 mm.	−1	1	1	5	4				
100 mm.	0			2	4				
102 mm.	2			1		2	1	1	
104 mm.	4							1	
106 mm. (III)	6						1		(IV)

$\rho = 0.796 +$ P. E. $\rho = \pm 0.0348 +$

A general tendency towards great length of tail in southern birds has been noted by Allen (**'71**, pp. 230, 231). In Table VII, p. 291, the mode of lengths of tail for Austroriparian males is seen to be 102 mm.; whereas Appalachian males have a mode of 100 mm. The mean of Austroriparian shrikes is 101.91 + mm., while that of Appalachian shrikes is 99.43 + mm.,

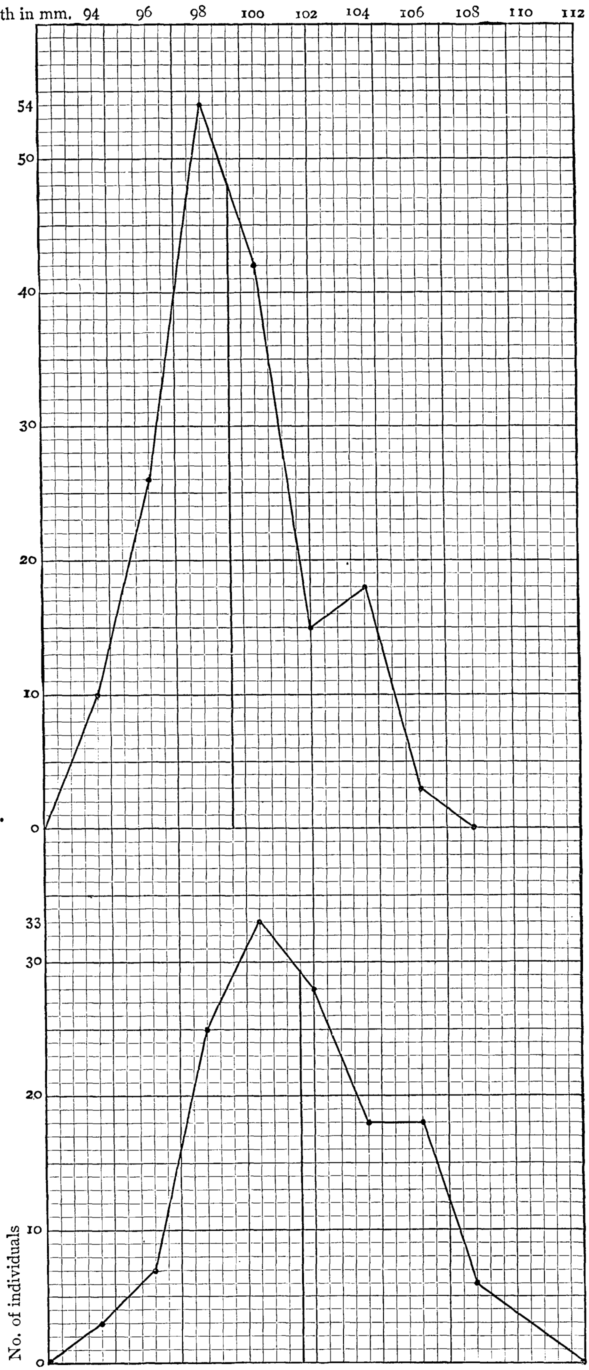

Fig. 4A.

Fig. 4B.

Fig. 4. — Frequency polygons. *A*, Classes of left wings for 168 males from entire region; *B*, tails of 141 males from entire region.

a difference of 2.48 mm. Austroriparian females show a still greater preponderance in length of tail, having a mode 6 mm. greater and a mean 3.05 mm. greater. Not much importance, however, can be attached to the great difference of the modes in this case, because of the small number of females measured.

Palmer ('98) says, in referring to shrikes of the Appalachian and Austroriparian subprovinces respectively: "In migrans

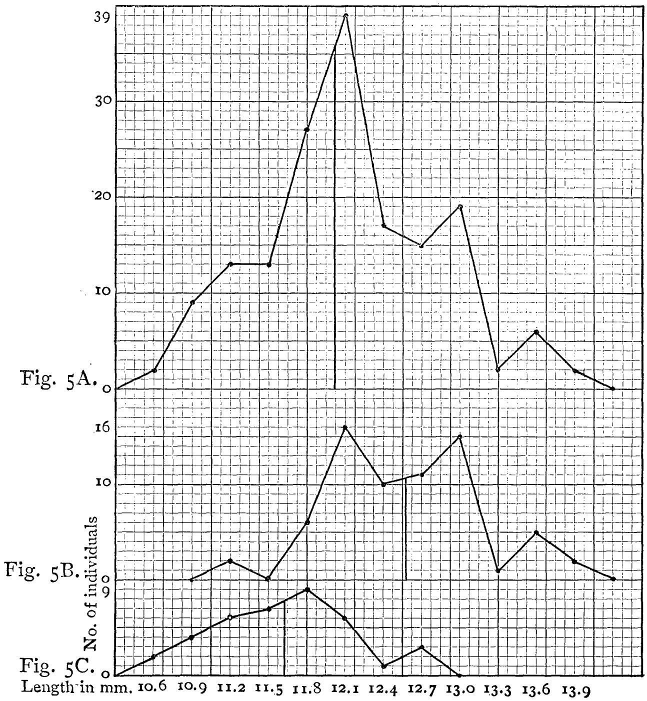

FIG. 5. — Frequency polygons for length of bill. *A*, 164 males from entire region; *B*, 69 males from Austroriparian subprovince; *C*, 38 males from Appalachian subprovince.

[Appalachian] the wing is longer than the tail, due to its migratory habit; in ludovicianus [Austroriparian] the tail is longest, thus indicating its fixed habitat."

I find, on the contrary, that the wing is not absolutely longer than the tail in the Appalachian form, though from Tables VI and VII, pp. 290, 291, it is clear that the excess of the length of tail over that of the wing is less in migrans than in ludovicianus;

or, in other words, that *relatively to the tail*, the wing is longer in migrans than in ludovicianus, as his theory would require.

Palmer's explanation of length of wing in migrans as the result of habit is plausible. However, it has not been proved that shrikes which migrate northward actually fly any more than those remaining in Florida; moreover, it seems to me that there are other possible explanations. I am inclined to think that we have here a case of the condition already noted

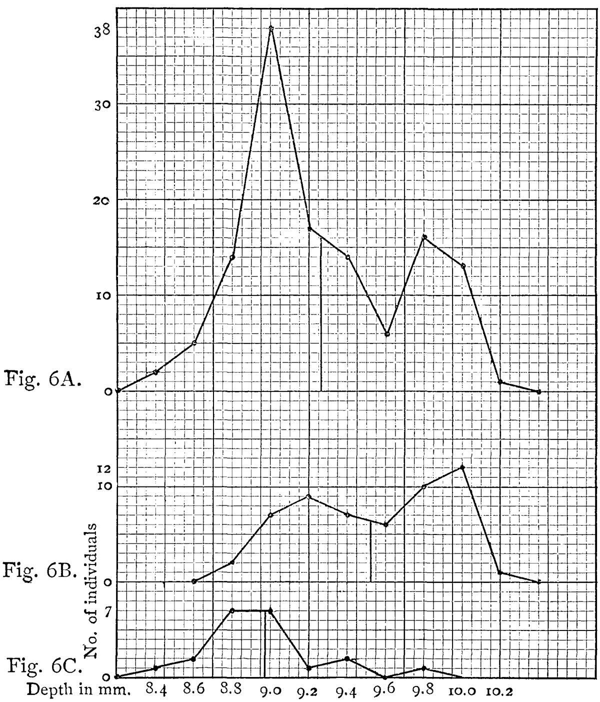

FIG. 6. — Frequency polygons for depth of bill. *A*, 126 males from entire region; *B*, 54 males from Austroriparian subprovince; *C*, 21 males from Appalachian subprovince.

by Allen — a tendency towards greater length of tail in tropical birds. Unfortunately I cannot prove this, — any more than Palmer does his hypothesis, — for it has not been possible to determine the actual ratios of tail length and wing length with reference to the general size of the bird.

2. *Length and Depth of Bill.* — In Fig. 5 are given frequency polygons of variations in length of bill for the entire region and

for two subprovinces. Here is shown a considerable separation of the means (indicated by the vertical line) for the subprovince polygons, indicating a larger bill for Austroriparian shrikes (5*B*), which are also seen in Fig. 6*B* to have a greater depth of bill. The increase in size found in the bills of Florida shrikes is also shown by comparison of Tables IV and V, in which these characters are correlated for a series of Florida[1] shrikes and a series from the Appalachian subprovince. A striking absence of correlation and a great tendency towards individual variation in the proportions of the bill are to be seen. Increase in the relative size of the bill in many southern birds has been noted by Allen ('71). It would be an interesting field for statistical investigation.

TABLE IV. — 32 MALE SHRIKES FROM FLORIDA.

Classes of Depth of Bill.	Classes of Length of Bill in Millimeters.										Total.
	11.2	11.5	11.8	12.1	12.4	12.7	13.0	13.3	13.6	13.9	
8.8 mm. . .				1	1						2
9.0 mm. . .				1			1				2
9.2 mm. . .				2		1			1	1	5
9.4 mm. . .			1				1		1		3
9.6 mm. . .					2						2
9.8 mm. . .			1	1		1	1		2		6
10.0 mm. . .			1	5	1		4				11
10.2 mm. . .						1					1
Total . . .			3	10	4	3	7		4	1	32

3. *Color.* — Frequency polygons for variations in the melanism of the head are shown in Fig. 7. The upper polygon (Fig. 7*A*), which includes the entire series, is seen to be distinctly bimodal, and in the lower polygons we see that the mode of greater melanism is due to the presence of Austroriparian shrikes, and that the shrikes of the Campestrian subprovince have the least melanism for the dorsal surface of the head.

[1] Only Florida representatives of the Austroriparian shrikes were taken in this case, in order to eliminate intermediate forms, for it seemed desirable to me to compare the Appalachian shrikes with a group as nearly tropical as possible.

The Campestrian subprovince includes arid portions of the United States, where paleness of color in the fauna is supposed to be correlated with this condition.

TABLE V. — 22 MALE SHRIKES FROM THE APPALACHIAN SUBPROVINCE.

Classes of Depth of Bill.	Classes of Length of Bill in Millimeters.									Total.
	10.6	10.9	11.2	11.5	11.8	12.1	12.4	12.7	13.	
8.4 mm.			1							1
8.6 mm.	1								1	2
8.8 mm.			1	3		1				5
9.0 mm.	1	1	2	1	1	1		1		8
9.2 mm.			1			1				2
9.4 mm.				1		1	1			3
9.6 mm.										0
9.8 mm.			1							1
Total.	2	1	6	5	1	4	1	1	1	22

While such correlations are frequently suggested by the fauna of desert regions, the relations of humidity to color are still problems for further investigation.

Very great variations in the melanism of the upper tail coverts are shown in Fig. 8. The shrikes of the Campestrian subprovince have here also a mode of little melanism, 30%, while a mode of great melanism, 70%, is found for Austroriparian shrikes. The upper tail coverts of Campestrian shrikes, especially those from Colorado and Arizona, are very light gray. This peculiarity has caused the race to be designated as the white-rumped shrikes.

B. Tables of Constants of Frequency Polygons.

In Tables VI–XIII will be found indices of variation for all the material studied. All computations have been made from measurements grouped into classes. This grouping has been adopted both in drawing the polygons and in determining the indices of variability, in order to reduce the "probable error."

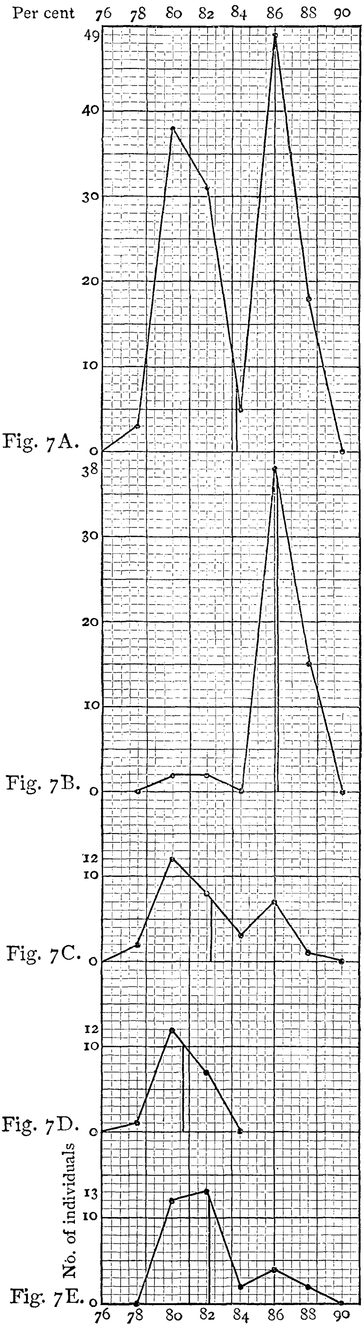

Fig. 7. — Frequency polygons for melanism of top of head. *A*, 144 males from entire region; *B*, 57 males from Austroriparian subprovince; *C*, 33 males from Appalachian subprovince; *D*, 21 males from Campestrian subprovince; *E*, 33 males from Sonoran subprovince.

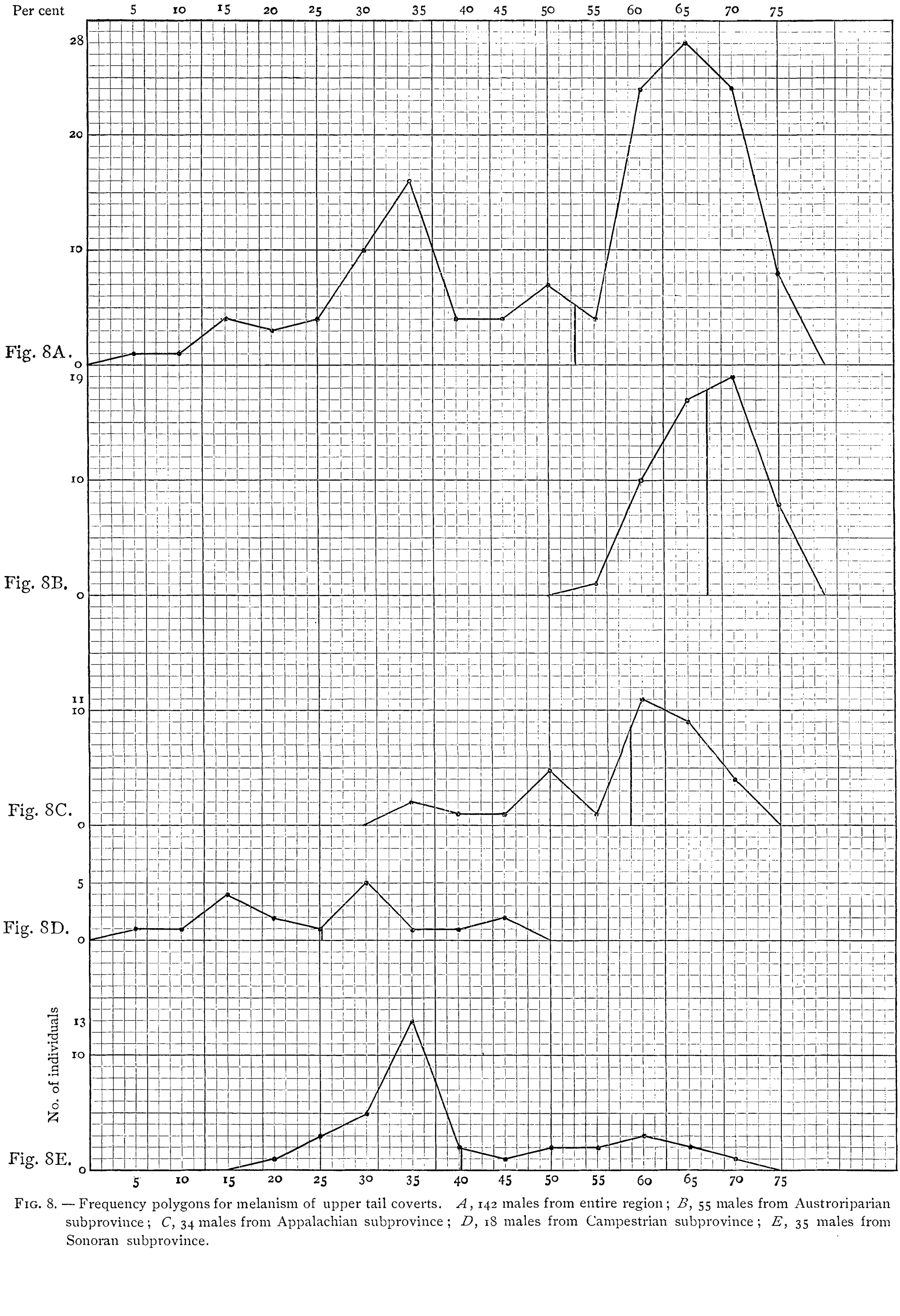

FIG. 8. — Frequency polygons for melanism of upper tail coverts. *A*, 142 males from entire region; *B*, 55 males from Austroriparian subprovince; *C*, 34 males from Appalachian subprovince; *D*, 18 males from Campestrian subprovince; *E*, 35 males from Sonoran subprovince.

The following constants of the frequency polygons have been determined (Davenport, '99):

1. Mode: Class of greatest frequency.
2. Mean: $M. = \frac{\Sigma (V. f)}{n}$.
3. Standard Deviation, $\sigma = \sqrt{\frac{\Sigma (x.^2 f)}{n}}$.
4. Coefficient of variability: $C.V. = \frac{\sigma}{M} \times 100$.
5. Probable error of Mean: $P. E. M.$ [sub.] $= \pm 0.6745 \frac{\sigma}{\sqrt{n}}$.
6. Probable error of Standard Deviation: $P. E. \sigma$ [sub.] $= \pm 0.6745 \frac{\sigma}{\sqrt{2n}}$.

TABLE VI. — LENGTH OF LEFT WING.

AREA.	MATERIAL.	MODE.	MEAN.	STANDARD DEV.
Entire region	168 males.		99.09 + mm.	2.79 + mm.
	112 females.		97.98 + mm.	2.64 + mm.
Austroriparian	70 males.	98 mm.	97.6 + mm.	2.04 + mm.
	31 females.	96 mm.	96.64 + mm.	2.35 + mm.
Appalachian	35 males.	98–100 mm.	99.2 mm.	2.45 + mm.
	25 females.	98 mm.	97.68 mm.	2.17 + mm.
Campestrian	27 males.	104 mm.	101.26 mm.	2.45 + mm.
	24 females.	102 mm.	99.75 mm.	2.79 + mm.
Sonoran	36 males.	98 mm.	100.28 mm.	2.90 + mm.
	32 females.	98 mm.	98.19 + mm.	2.36 + mm.

$C.V.$ of 168 males = 2.81 +. $C.V.$ of 112 females = 2.69 +.

$P. E. M.$ [sub.] 168 males = ± 0.145.

$P. E. \sigma$ [sub.] 168 males = ± 0.1026 +.

TABLE VII. — LENGTH OF TAIL.

AREA.	MATERIAL.	MODE.	MEAN.	STANDARD DEV.
Entire region .	141 males.		101.55 + mm.	3.49 + mm.
	95 females.		99.55 + mm.	3.63 + mm.
Austroriparian .	65 males.	102 mm.	101.91 + mm.	3.12 + mm.
	30 females.	104 mm.	100.47 + mm.	3.25 + mm.
Appalachian . .	28 males.	100 mm.	99.43 + mm.	3.06 + mm.
	19 females.	98 mm.	97.42 + mm.	3.85 + mm.
Campestrian . .	20 males.	104 mm.	102.3 mm.	3.48 + mm.
	18 females.	102 mm.	99.89 + mm.	3.42 + mm.
Sonoran . . .	28 males.	100 mm.	102.21 + mm.	3.90 + mm.
	28 females.	102 mm.	99.43 + mm.	3.88 + mm.

CV. of 141 males = 3.43 +. *CV.* of 95 females = 3.65 +.
P. E. M [sub.] 141 males = ± 0.198 +.
P. E. σ [sub.] 141 males = ± 0.14008 +.

TABLE VIII. — LENGTH OF BILL.

AREA.	MATERIAL.	MODE.	MEAN.	STANDARD DEV.
Entire region .	164 males.		12.01 + mm.	0.71 + mm.
	112 females.		11.71 + mm.	0.63 + mm.
Austroriparian .	69 males.	12.1 mm.	12.58 + mm.	0.59 + mm.
	30 females.	12.1 mm.	12.17 + mm.	0.51 + mm.
Appalachian . .	38 males.	11.8 mm.	11.63 + mm.	0.56 + mm.
	29 females.	11.9 mm.	11.26 + mm.	0.54 + mm.
Campestrian . .	25 males.	12.1 mm.	11.84 + mm.	0.63 + mm.
	20 females.	12.1 mm.	11.57 + mm.	0.51 + mm.
Sonoran . . .	32 males.	12.1 mm.	11.96 + mm.	0.54 + mm.
	35 females.	12.1 mm.	11.76 + mm.	0.53 + mm.

CV. of 164 males = 5.89 +. *CV.* of 112 females = 5.35 +.
P. E. M. [sub.] 164 males = ± 0.0374 +.
P. E. σ [sub.] 164 males = ± 0.0264 +.

TABLE IX. — DEPTH OF BILL.

AREA.	MATERIAL.	MODE.	MEAN.	STANDARD DEV.
Entire region	126 males. 85 females.		9.27 + mm. 8.95 + mm.	0.42 + mm. 0.41 + mm.
Austroriparian	54 males. 22 females.	10.0 mm. 9.2 mm.	9.54 + mm. 9.32 + mm.	0.38 + mm. 0.37 + mm.
Appalachian	21 males. 19 females.	8.8–9.0 mm. 8.8 mm.	8.95 + mm. 8.90 + mm.	0.30 + mm. 0.36 + mm.
Campestrian	19 males. 14 females.	9.0 mm. 8.8 mm.	9.08 + mm. 8.8 + mm.	0.28 + mm. 0.30 + mm.
Sonoran	32 males. 30 females.	9.0 mm. 8.8–9.0 mm.	9.12 + mm. 8.78 + mm.	0.44 + mm. 0.36 + mm.

C.V. of 126 males = 4.57 +. *C.V.* of 85 females = 4.61 +.
P. E. M. [sub.] 126 males = ± 0.0252 +.
P. E. σ [sub.] 126 males = ± 0.0178 +.

TABLE X. — MELANISM OF TOP OF HEAD.

AREA.	MATERIAL.	MODE.	MEAN.	STANDARD DEV.
Entire region	144 males. 99 females.		83.57 + %. 83.66 + %.	3.00 + %. 3.19 + %.
Austroriparian	57 males. 24 females.	86%. 88%.	86.17 + %. 87.25 + %.	1.69 + %. 1.81 + %.
Appalachian	33 males. 25 females.	80%. 80%.	82.24 + %. 82.32 + %.	2.68 + %. 3.03 + %.
Campestrian	21 males. 17 females.	80%. 80%.	80.67 + %. 80.94 + %.	1.13 + %. 1.78 + %.
Sonoran	33 males. 33 females.	82%. 82%.	82.24 + %. 83.45 + %.	2.4 + %. 2.38 + %.

C.V. of 144 males = 3.58 +. *C.V.* of 99 females = 3.81 +.
P. E. M. [sub.] 144 males = ± 0.1686.
P. E. σ [sub.] 144 males = ± 0.119 +.

TABLE XI. — MELANISM OF UPPER TAIL COVERTS.

AREA.	MATERIAL.	MODE.	MEAN.	STANDARD DEV.
Entire region .	142 males.		53.13 + %.	15.42 + %.
	104 females.		47.98 + %.	18.99 + %.
Austroriparian .	55 males.	70%.	67.22 + %.	5.02 + %.
	25 females.	65%.	66.2 %.	8.16 + %.
Appalachian . .	34 males.	60%.	58.38 + %.	9.3 + %.
	20 females.	60%.	53.2 %.	6.4 + %.
Campestrian . .	18 males.	30%.	25.28 + %.	11.4 + %.
	17 females.		28.25 + %.	14.8 + %.
Sonoran . . .	35 males.	35%.	40.43 + %.	13.01 + %.
	43 females.	30%.	38.26 + %.	13.37 + %.

C.V. of 142 males = 29.02 +. *C.V.* of 104 females = 39.58 +.
P. E. M. [sub.] 142 males = ± 0.873 +.
P. E. σ [sub.] 142 males = ± 0.617 +.

TABLE XII. — MELANISM OF BREAST.

AREA.	MATERIAL.	MODE.	MEAN.	STANDARD DEV.
Entire region .	124 males.		31.21 + %.	11.07 + %.
	98 females.		36.58 + %.	10.51 + %.
Austroriparian .	42 males.	25%.	23.81 + %.	6.66 + %.
	27 females.	35%.	32.41 + %.	10.36 + %.
Appalachian . .	35 males.	35%.	43.28 + %.	9.4 %.
	23 females.	40%.	47.61 + %.	8.71 + %.
Campestrian . .	17 males.	25%.	27.65 + %.	7.27 + %.
	18 females.	35%.	31.39 + %.	6.63 + %.
Sonoran . . .	30 males.	25%.	29.5 %.	6.65 + %.
	30 females.	35%.	35.0 %.	7.30 + %.

C.V. of 124 males = 35.48 +. *C.V.* of 98 females = 28.72 +.
P. E. M. [sub.] 124 males = ± 0.6709 +.
P. E. σ [sub.] 124 males = ± 0.474 +.

Because of limited time I was unable to obtain measurements of culmen curvature for more than forty-seven individuals (partly males and partly females), a number so small that a rather large probable error is found for coefficients of variability.

The results obtained are given in the following table.

TABLE XIII. — CURVATURE OF CULMEN.

	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	36°	MEAN.
Austroriparian	1					1	1	1	2						28.66° +
Appalachian .				3	2	2	4	5	2	3	1				29.32° +
Campestrian .					2	4	1	1	1	0	2	2	2	1	31.00°
Sonoran . .								1	1				1		32.00°
Total. . . .	1			3	4	7	6	8	6	3	3	2	3	1	29.936°

Austroriparian	$\sigma = 2.74° +$.	$C.V. = 9.58 +$.	$P. E. \sigma = \pm 0.534 +$.
Appalachian	$\sigma = 2.03° +$.	$C.V. = 6.92 +$.	$P. E. \sigma = \pm 0.206 +$.
Campestrian	$\sigma = 3.12° +$.	$C.V. = 10.06 +$.	$P. E. \sigma = \pm 0.372 +$.
Sonoran	$\sigma = 2.16° +$.	$C.V. = 6.75$.	$P. E. \sigma = \pm 0.594 +$.
Total	$\sigma = 2.74° +$.	$C.V. = 9.15 -$.	$P. E. \sigma = \pm 0.191 +$.

The shrikes of the Austroriparian subprovince, mostly Florida birds, are seen to have a mean curvature 3.34°—less than that of the Sonoran birds measured. With so few individuals precise statements as to curvature are not very reliable, but I believe that the figures given are approximately correct for the four subprovinces represented. The series of measurements of the curvature of the culmen when half the base line *A B* (Fig. 3) was used as the chord gave the following constants and coefficients of variability for the forty-seven individuals measured in the first series: Mean, 26.34° +; Mode, 27°; $\sigma = 2.33° +$; $C.V. = 8.85$; $P. E. \sigma = \pm 0.162 +$.

The angles obtained from the second series of measurements were never greater than those from the first series. The greatest deviation from the first set of measurements was 7°, which occurred in four cases. All the deviations are indicated in the following table:

0°	1°	2°	3°	4°	5°	6°	7°	
4	2	6	10	10	7	4	4	individuals.

It was impossible to get as accurate results in the second series, because of greater difficulty in determining the actual point of tangency, but the results obtained show that there is a fairly close correlation in the curvature for various parts of the bill; that is, where the culmen is much curved in one place, it is likely to have correspondingly strong curvature at other points.

The only selection exercised in the whole work was employed in the estimation of curvature, individuals which appeared on inspection to be typical for their respective subprovinces having been chosen, since it was impossible, for want of time, to photograph the entire series.

C. *Discussion of Results and Conclusions.*

Although computations have been carried out to the third or fourth decimal place, figures beyond the second decimal place are not given, as they would imply a degree of precision which is not attainable in an investigation of this kind. For example, the mean length of wing for 168 male shrikes is seen to be (see Table VI) 99.09 + mm. It often happened in making correlations that, because of general wear or some special mutilation to a single character, some individuals could not be included in a correlation table. This has happened especially often in the case of the tail, so that in the correlation table for wings and tails only 140 of the 168 male shrikes could be included. The mean for the left wings of the series of 140 shrikes was found to be 99.06 mm. (see Table I), a result which differs from the mean of the whole lot (168) by 3 in the second decimal place.

The modes and means given for the melanism of the breasts of Appalachian-subprovince shrikes show a percentage which, though higher than in other subprovinces, is not as high as would have been the case had not a large proportion of individuals come from localities intermediate between the Campestrian and Appalachian subprovinces. Shrikes from New England were found to have 50–60% of melanism for the breast. An analysis of material shows that only five skins

were obtained from New England, whereas Illinois alone is represented by thirteen. This lack of equalization in the sources of material prevents certain desirable interpretations of tendencies towards minor variations.

To my mind one of the most important results reached is the determination of the relative variability of different characters in a group of birds representing geographical areas of considerable size. The coefficients of variability (Tables VI–VII) indicate for the wing and tail a variability of less than 4 in length. The bill is somewhat more variable, as is shown by a coefficient of 5.89 + for the length of bill in a series of 164 males. Color, as would be expected, is much more subject to variation. The upper tail coverts and breast are the most variable; but the coverts furnish only a very small part of a bird's coloration, and the color of the breast was the character which it was the most difficult to measure satisfactorily, especially as advanced age and the condition of the plumage are factors of possible importance which I have found it difficult to consider. Fortunately for this particular study, shrikes do not change much after the first winter plumage is obtained.

I believe that migrans is as worthy of recognition as gambelli. Whether it is profitable to encumber nomenclature with the names of these races, based on slight variations, is a question which is worthy of further consideration.

The power of discriminating fine shades of color varies in different persons, and it can be highly developed by education. At the present time there is much activity among certain systematists in the production of new subspecies for geographical varieties, which long experience and special adeptness enable them to distinguish. A variation, no matter how slight, that can be correlated with geographical range is considered to warrant an addition to nomenclature; but the discovery and description of geographical races can be carried on almost *ad infinitum*.

Birds, because of their powers of flight, might be expected to be less subject to the factor of isolation than non-migratory animals, but the tendency to return in spring to the same breeding place must, in some species at least, be conducive to

the formation of numerous local variations, or family characteristics, whose recognition is a matter of power of discrimination on the part of the systematist.

It seems highly desirable that the question of limiting the establishment of new subspecies or varieties by some generally accepted criteria be considered.

I do not argue for the universal use of the method of the "Precise Criterion," but I believe that it is both desirable and practicable to employ it in certain problems of taxonomy, such, for instance, as the one just discussed. The ordinary work of classification, perhaps, does not at present require the precision in treatment furnished by purely quantitative methods, but problems of race distinction, I believe, need the precision of the "Precise Criterion." The contention that quantitative methods are less useful than those ordinarily employed because of the large amount of material required, is mischievous, for it argues that generalizations professing precision are possible by methods which are not precise. The problems of finer classification can be properly settled only by the use of a large amount of material, whatever the methods used.

V. Summary.

Quantitative methods have here been applied to the study of variation in the smaller shrikes of North America, and the following variable characters have been measured:

1. Length of wing.
2. Length of tail.
3. Length of bill.
4. Depth of bill.
5. Curvature of culmen.
6. Color of dorsal surface of head.
7. Color of upper tail coverts.
8. Color of breast.

The three color areas have been found to vary principally in the amount of melanism present. A series of 294 shrike skins from various parts of the United States, Mexico, and southern Canada have been studied and measurements of these skins have been classified.

Coefficients of variability have been determined as follows for the whole series.

	Males	Females
Length of wing	2.81 +	2.69 +
Length of tail	3.43 +	3.65 +
Length of bill	5.89 +	5.35 +
Depth of bill	4.57 +	4.61 +
Melanism of top of head	3.58 +	3.81 +
Melanism of upper tail coverts	29.02 +	39.58 +
Melanism of breast	35.48 +	28.72 +
Curvature of culmen . . 47 males and females 9.15 –		

Florida shrikes were found to have relatively large bills and long tails.

A large percentage of melanism has been found for the top of head and the back of shrikes from the south central states, while shrikes from the vicinity of Colorado and Arizona have a relatively small percentage of melanism for all three color surfaces measured.

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